



Livestock grazing activities and wild boar rooting affect alpine earthworm communities in the Central Pyrenees (Spain)



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ABSTRACT

In alpine areas, shifts in traditional grazing activities are globally affecting ecosystem properties and rural livelihoods. The ongoing decrease in extensive husbandry, with a decline in sheep numbers and a relative increase in cattle stocking rates, has resulted in the abandonment of large alpine grazing areas. This pastoral change has been recently associated with increased disturbances of wild boar (*Sus scrofa*), mainly within cattle-stocked ranges. In turn, cattle areas favor earthworm communities, a preferred trophic resource for wild boars in mountain environments. However, it is unknown whether wild boar disturbances, together with grazing activities, can affect earthworm communities. Our aim is to analyze the abundance, richness and ecological categories of earthworms and soil parameters (soil C and N concentrations, moisture, and C:N ratio) in relation to the occurrence of wild boar disturbances and grazing activities at different stocking pressures. We sampled two different grazing scenarios differing in the distribution of cattle along a grazing gradient, which was represented by three levels of stocking pressure (high, intermediate and low). Our results showed a complex effect of grazing activities and disturbances on the abundance and richness of earthworms, along with variations in C:N ratio and soil moisture, especially with increasing cattle presence. At high-stocking pressures differences in earthworm abundance and richness between disturbed and undisturbed areas were limited, whereas at intermediate-stocking pressures earthworms were favored by wild boar disturbances. Ecological categories of earthworms responded differently; endogeic species were the most affected by grazing pressures and wild boar rooting, with highest occurrence at high-stocking pressures and within boar disturbed areas. In sum, pastoral use and soil disturbances affected earthworm community structure and composition in complex ways. These results indicate an interaction of processes that is relevant to understand current changes in alpine ecosystems.

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1. Introduction

Alpine ecosystems are of high natural value and one of the areas with the highest conservation priority in Europe (92/43/EEC, of 21 May 1992). These habitats also have a high socio-economic value; traditional use of these areas for extensive husbandry during the last centuries has supported local economies, preserving cultural values and generating high quality products (Luick, 1998). In the last 100 years, land use changes have had a significant impact on the structure and use of alpine ecosystems. The abandonment of extensive husbandry, with a sharp decline of sheep herding and a

relative increase of less-demanding cattle herds (Gartzia et al., in press; Lasanta-Martínez et al., 2005), together with extensive reforestation policies since the 1950s, have led to a gradual increase in forested areas (Boix-Fayos et al., 2007; Mather, 2001). The increase of forest cover has resulted in the expansion of the potential habitat for the wild boar (*Sus scrofa* L.). This circumstance, along with the gradual decline of the boar's large predators (bears and wolves), have led to a substantial increase of European populations of wild boar in the last decades (Apollonio et al., 2010; Barrios-García and Ballari, 2012).

Wild boars' omnivorous diet and their enormous adaptability are key factors to their population success (Barrios-García and Ballari, 2012). As they search for belowground feeding resources, such as plant rhizomes, bulbs and earthworms, wild boars may turn over hundred of hectares locally, generating extensive disturbances to crops, forests and natural grasslands worldwide (Apollonio et al., 2010; Barrios-García and Ballari, 2012; Bueno et al., 2009; Massei

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and Genov, 2004). These disturbances are of particular concern when they affect human activities. For example, in the Central Pyrenees (Spain), wild boar disturbances can affect up to 20% of alpine and subalpine grasslands used by domestic cattle, and are perceived by ranchers as a threat to their livelihoods (Bueno, 2011; Bueno et al., 2010).

One of the main attractants for wild boar rooting activity, especially in alpine environments, is the abundance of a valuable food item: earthworms (Baubet et al., 2003, 2004; Edwards, 1994). For example in the French Alps, the frequency of earthworm occurrence in wild boar diet is around 92% (Baubet et al., 2003). Earthworm abundance is positively related to the presence of livestock, because of the increased fertilization through dung deposition (Mijangos et al., 2006; Paoletti, 1999; Smith et al., 2008). However, at high stocking pressures, cattle trampling may negatively affect earthworm abundance (Cluzeau et al., 1992; Ligthart, 1997); therefore, earthworm abundance can be expected to be highest at intermediate stocking pressures. Similarly, the occurrence of wild boar disturbances is highest at intermediate stocking pressures (Bueno et al., 2010), which suggests that the occurrence of these disturbances might be linked to the abundance of earthworms. In any case, our knowledge of earthworm communities in alpine and subalpine environments is still limited.

In turn, wild boar disturbances modify physical and chemical properties of soils (Bueno et al., 2013; Lacki and Lanciá, 1983) and, together with grazing management practices, could affect earthworm communities, altering habitat suitability for earthworms. Recent changes in alpine habitats (i.e. an abandonment of extensive grazing areas together with an increment of wild boar disturbances) could lead to changes in the functional composition of earthworms, because different species and ecological categories (sensu Bouché, 1977) are known to respond differently to disturbances (Curry, 1998; Lavelle, 1988). Epigeic species, small superficial earthworms with exclusive litter diet, are very sensitive to the treading under high stocking rates. In contrast, the same scenario could be favorable to anecic species, which live in deep burrows and are able to escape easily by retreating into their burrows (Schon et al., 2011). However, wild boar disturbances may instead disrupt these burrows, having a negative impact on anecic species. On the other end, endogeic species, which live deeper in the soil and feed mainly on mineral soil particles, might be the most favored by wild boar disturbances. Boars' disturbances allow more nutrients to reach deeper in the soil, where endogeic species are safer from wild boar foraging. In fact, endogeic earthworms are the only ecological category not found in boar's diet so far (Schley and Roper, 2003). In any case, the effects of wild boar disturbances and grazing management on earthworm communities are still unknown in alpine environments. Studies addressing the separate and combined effects of these concurrent changes are critical for understanding grazing abandonment processes in mountain ecosystems.

This paper aims to analyze the effect of livestock grazing activities and wild boar disturbances in the abundance, richness, ecological categories of earthworms, and soil properties, in two representative scenarios of extensive husbandry in the Pyrenees. In addition, this paper will contribute to the knowledge of earthworm community composition in relation to human management of alpine grasslands of the Central Pyrenees. This will help to cover the important knowledge gaps on the biogeographic distribution of these organisms (Decaëns, 2010). In turn, the ecological role of earthworms might be relevant in key soil processes for the functioning of the entire system (Edwards, 1994; Knight et al., 1992; Lawton, 1994; Paoletti, 1999). Earthworms are known to affect soil properties, through increasing soil porosity, aeration and water dynamics, and mineralization and humification of organic matter, especially increasing nitrogen availability for plants (Lavelle, 1988; Parmelee et al., 1998). Based on previous knowledge of soil

disturbance and cattle grazing, we would expect two contrasting results. First, wild boar disturbances may negatively affect the abundance and richness of earthworms. Boars' disturbances increase soil compaction, through the removal of plant roots and the collapse of the soil gaps occupied by those roots, what is exacerbated by livestock treading (Bueno et al., 2013). This would degrade earthworm habitats and homogenize the diversity of niches, already limited in harsh environments (Decaëns, 2010). Another negative effect would also be expected, because wild boars feed on earthworms (Baubet et al., 2004). Secondly, if fertilization by livestock has a stronger or combined effect with wild boar disturbances on earthworm habitats, new niches with high nutrient availability for earthworms may be created. In this case, an enhancement of their abundance and richness could be expected.

2. Materials and methods

2.1. Study area and wild boar rooting

The study was conducted in two grazing areas of subalpine grasslands in the Spanish Central Pyrenees, Góriz, in Ordesa and Monte Perdido National Park (OMPNP; 42°36' N, 0°01' E), and Aisa, located on top of Aisa Valley (42°44' N, 0°35' W). The climate is alpine, with annual average temperature and precipitation of 5 °C and 1720 mm respectively (García-González et al., 2007). Lithology comprised mainly calcareous substrates such as limestone, sandstone and flysch (an overlaying complex of marlstone and sandstones) (Badía et al., 2002). Grazing activities in the Pyrenees have shifted from sheep to cattle ranching and extensive husbandry has declined in the last decades (Gartzia et al., in press; Lasanta-Martínez et al., 2005).

Wild boar rooting is a large soil disturbance with highly variable extent but a relatively homogeneous depth (10 cm depth, on average in these grasslands) (Bueno et al., 2013; Groot Bruinderink and Hazebroek, 1996; Kotanen, 1994; Tierney and Cushman, 2006). This disturbance is created when wild boars search for a variety of belowground feeding resources. One particularly appreciated food item, especially in mountain areas, are earthworms (Baubet et al., 2004). Wild boar rooting occurs especially in dense alpine grasslands and is directly related to cattle grazing activities (Bueno et al., 2009); rooting can affect more than 20% of cattle stocking areas (Bueno et al., 2010), significantly reducing the pastoral values of these grasslands (Bueno et al., 2011).

2.2. Stocking pressures and grazing gradient scenarios

In this study, we analyzed a grazing gradient, from high- to low-stocking pressures, commonly described in different alpine and subalpine areas of Europe (Badía et al., 2008; Common et al., 1998). High-stocking pressure sites were represented by areas within livestock resting places and around shepherd's huts. These areas are normally dominated by tall, nitrophilous plants of the phytosociological alliance *Rumicion pseudoapini* (Table 1). Intermediate-stocking pressure sites were chosen in adjacent areas, with some evidence of livestock use (e.g., presence of cattle dung). These areas are commonly dominated by a highly diverse suite of species within the Alliance *Bromion erecti* (Table 1). Finally, the areas with low-stocking pressure were located where livestock, particularly cattle, does not graze often. These areas are dominated by *Nardus stricta*, a species not very palatable for livestock (Chadwick, 1960) but edible for earthworms (Knapp et al., 2012), within the Alliance *Nardion strictae* (Table 1). High- and intermediate-stocking pressure areas are spatially distributed at the valley bottoms, where livestock moves without difficulties and plant productivity is higher. Low-stocking pressure areas were

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